# User Manual

## 123electric

## Battery Management System

## " 123\BMS"

**Revision 1.4 Augusts 2015**

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## Introduction

After the introduction of affordable Lithium-Ferro-Phosphate batteries, finally electric cars, boats, and motorcycles have become feasible.
However, LiFePO4-batteries can easily be over-charged, or over-discharged. It is therefore vital that these batteries are treated very carefully. For a maximum range, and a long life, intelligent 'battery management' is of utmost importance.

The 123electric Battery Management System ( or short : "BMS" ) is primarily intended for prismatic LiFePO4-cells, but can also be adapted by the end-user for other cells like Li-Ion and LiPo, provided the cell-voltage is in the range of 2V to 5V.

## System structure

The 123electric BMS is designed for battery-packs that have many cells in series, to form a high voltage battery-pack. Each cell is equipped with a small BMS-board, that monitors cell parameters like cell-number, cell-voltage, cell-temperature and bypass-current. These boards send this data via a one-wire interface to the BMS-controller. This controller collects all this data, and displays that via a USB-interface on a Windows Computer.
A free downloadable "electronic dashboard" ( http://www.123electric.nl/software ) tells you in the blink of an eye, what the status of the battery-pack is. In the 'settings-menu' of this program the user can adapt the system to his personal requirements :

- Volt meter range ( 5 choices )
- Current meter range ( 3 choices, depending on the current sensor used )
- Cell Capacity ( 10 - 999 Ah )
- Charging Algorithm ( balanced -, quick- or emergency- charge )
- Real Time Clock ( 24 h )
- Charging start time
- Charging stop time
- Minimum Charging Current ( depending on charger used )
- Maximum Charging Current ( depending on charger used )

- Minimum Cell Voltage ( error-level )
- Maximum Cell Voltage ( error-level )
- Bypass Voltage ( balancing voltage )
- Recharge Voltage ( charge refresh )
- Minimum Cell Temperature ( error-level )
- Maximum Cell Temperature ( error-level )
- Gauge linearization ( for current- and capacity- gauge )
- External current meter-scale selection

The 123\BMS-controller can be connected with most chargers from the TC/Elcon-range, via the three-wire control-connector. ( No CAN option required )

To indicate an error-condition, two relay-outputs are available :
one output (Ry2) is active to indicate that the charger is still connected to the mains, and the other output (Ry3) tells you that the communication between the cell-boards is lost **and/o**r that one cell exceeds maximum temperature **and/or** the cell-voltage is outside the specified range.

For those who convert a car into an electric vehicle the 123\BMS-controller supplies an output that mimics the float-resistor in a fuel tank. With this feature one may decide to use the already existing gauge as a remaining capacity ( ‘fuel’ ) indicator. A second output is available to indicate the actual current. The electronic dashboard offers a simple way to linearise almost any gauge.

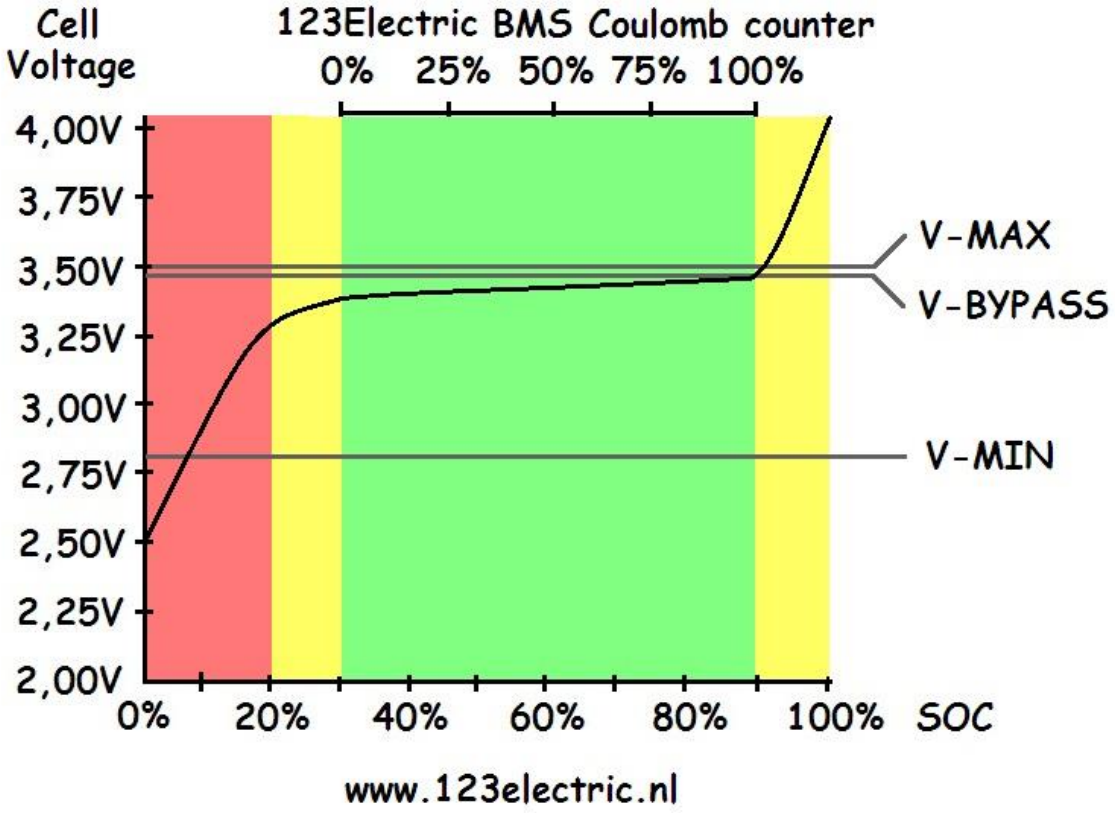
## Keep the batteries in a perfect condition : ALWAYS !

The drawing below shows that your expensive batteries are in good hands with 123 electric. The 123\BMS-system pre-sets the Coulomb counter to 100% when either all cells get to V-bypass **or** when one cell reaches V-max. (You can change these voltage settings with the electronic dashboard by yourself )

Note : the Coulomb counter is also set to 100% after a power-down.

The left side of the green ( “safe” ) area, can also be set by yourselves. If you use 90 Ah cells for instance, and you only want to use 60% of the capacity, you can enter 60% of 90 Ah = 54 Ah in the field for Cell-capacity.

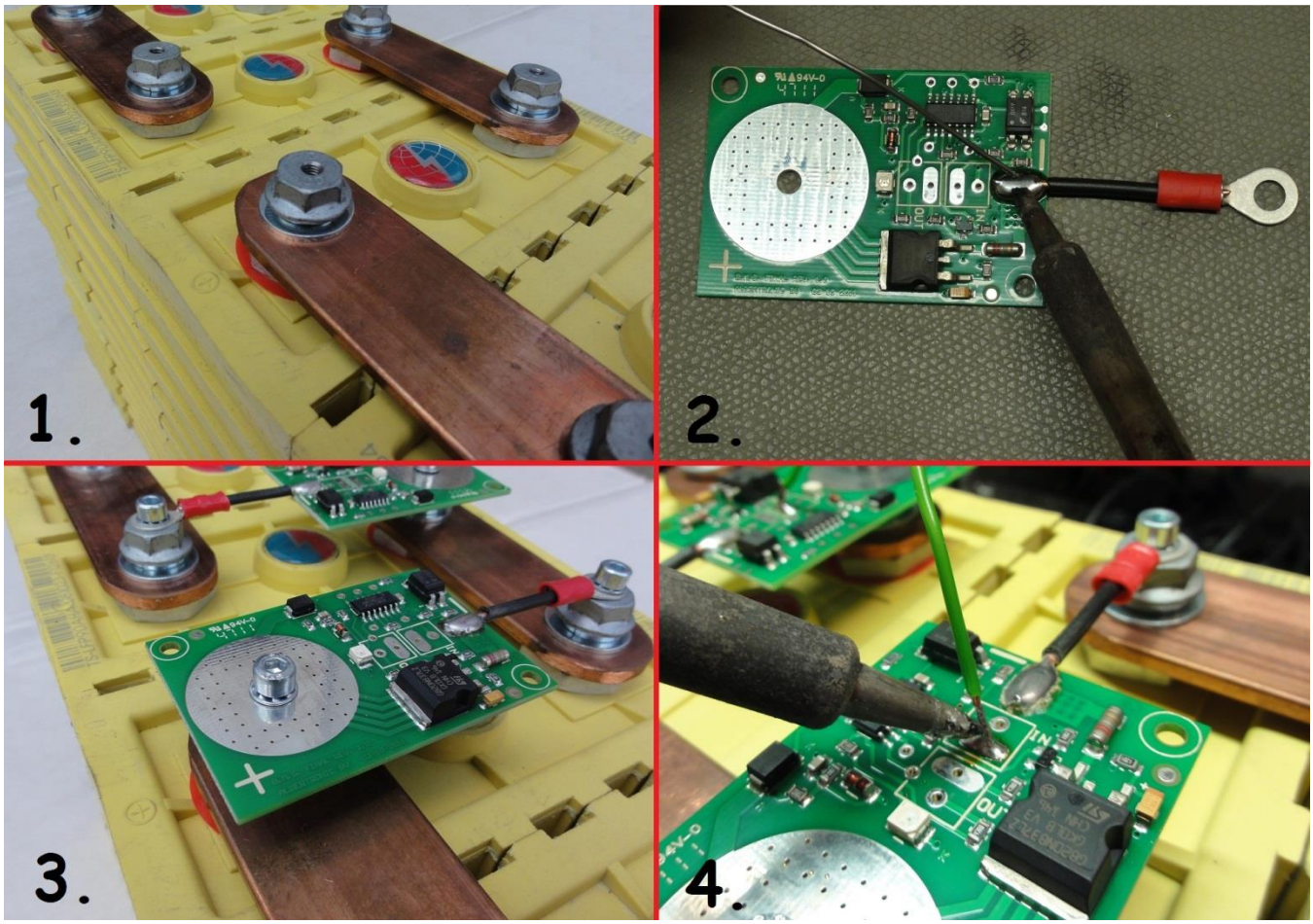
Conclusion : the upper limit is safe-guarded by entering V-max / V-bypass, and the lower limit by Cell-capacity ( and on top of that, an error-condition is issued when one cell gets lower then Vmin, so you can be pretty sure you are never ruining your cells )



# Specifications

| | |
|---|---|
| Supply-voltage of BMS-controller | 8-30 Volts DC |
| Idle current of the BMS-controller inclusive current sensor | < 0.007 Amp. |
| Number of cells | 2 - 255 |
| Balancing current | 1 Amp. ( regardless of cell-voltage ) |
| Idle-current BMS-board | < 100 micro Amp. |
| Current-sensor | 100 / 200 or 400 Amp. |
| A/D-resolution | 1024 steps ( 10 bit ) |
| Cell-voltage | in steps of 0,01 Volt ( 2,00 – 5,00 V ) |
| Cell-temperature | in steps of 1 degree ( -40 to 99 Celsius ) |
| Scan-time per cell | 0,015 Seconds |
| Factory-settings | Vmin = 2,50 Volt<br>Vmax = 3,75 Volt<br>Vbyp = 3,40 Volt<br>Vchg = 3,00 Volt<br>Tmin = + 0 degrees Celsius<br>Tmax = +60 degrees Celsius |

# BMS Board mounting




**WARNING :** be aware that your battery-pack contains a large amount of energy, which can be **potentially lethal**. Use isolated spanners, to prevent any short circuits.
High inrush currents ( causing sparks and ultra-high electro magnetic levels ) can easily damage the electronic circuits.
We therefore **strongly recommend** to connect all large current connections **first** and to connect the BMS-boards **later**.

A good way of doing this is indicated on photo number one. Standard M8-bolts are modified with an M4 threaded hole in the top. After thorough cleaning of the cell-poles, the copper strips are bolted-on using a good anti-oxidant joint compound like NOALOX. Don't forget to **also** attach wires to the first and last cell in the same way, and connect these to the charger and the motor-controller.

Now, prepare the BMS-boards as shown on photo number two. Use thick solid-copper wire for this, for optimum accuracy. ( the bypass-current has to flow through these wires )
Take your time : the end-result has to look good !

Connect all the boards as shown in photo number three. The BMS-board always to be mounted on the 'plus'-pole of the cell. This '+' is also indicated on the board.

Remember to use an 'IN'-board for the first cell, and an 'OUT'-board for the last cell.
( see "wiring diagram overview" )

Might you have two battery packs, like one in front and the other in the back of a car, you will have to equip each individual pack with its own 'IN' and 'OUT'-board. ( see "split pack wiring overview" )

For optimum noise-immunity the wiring from- and to- the "IN" and "OUT" boards, will have to be so called "twisted-pair". ( see "wiring diagram overview" and/or "split pack wiring overview" )

It speaks for itself, that if you would plan to use for instance three packs, that you will have to order three "IN"-boards, and three "OUT"-boards.

The one-wire interconnect should be soldered as indicated in the diagrams. Use a small soldering-iron, and take your time to do this job VERY carefully. The quality of your work effects reliability greatly.

NOTE: Make sure the BMS boards are located in a dry and dust free area, otherwise we advise to use a PCB coating, to be applied after the installation is completed.

# Cell Board LED

When the system is installed properly, the Green LED on the cell board will tell you some information.

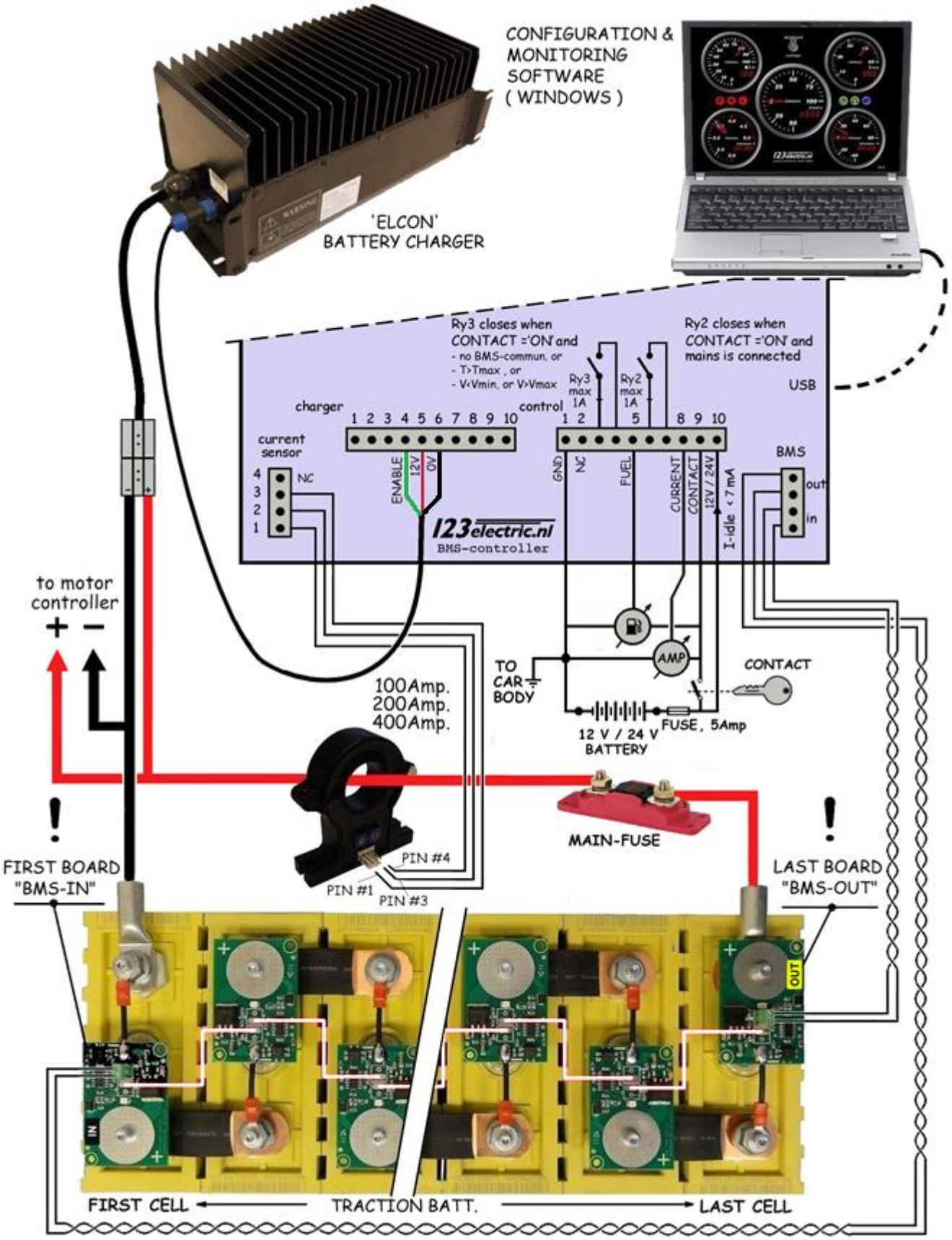
-When the system is in idle mode the LED will flash one time in four seconds.

- When the system is active (this means: charger activated or 12 Volt contact voltage on Pin number 9 of the control connector) the LED will flash more often for more accurate information of the cells.

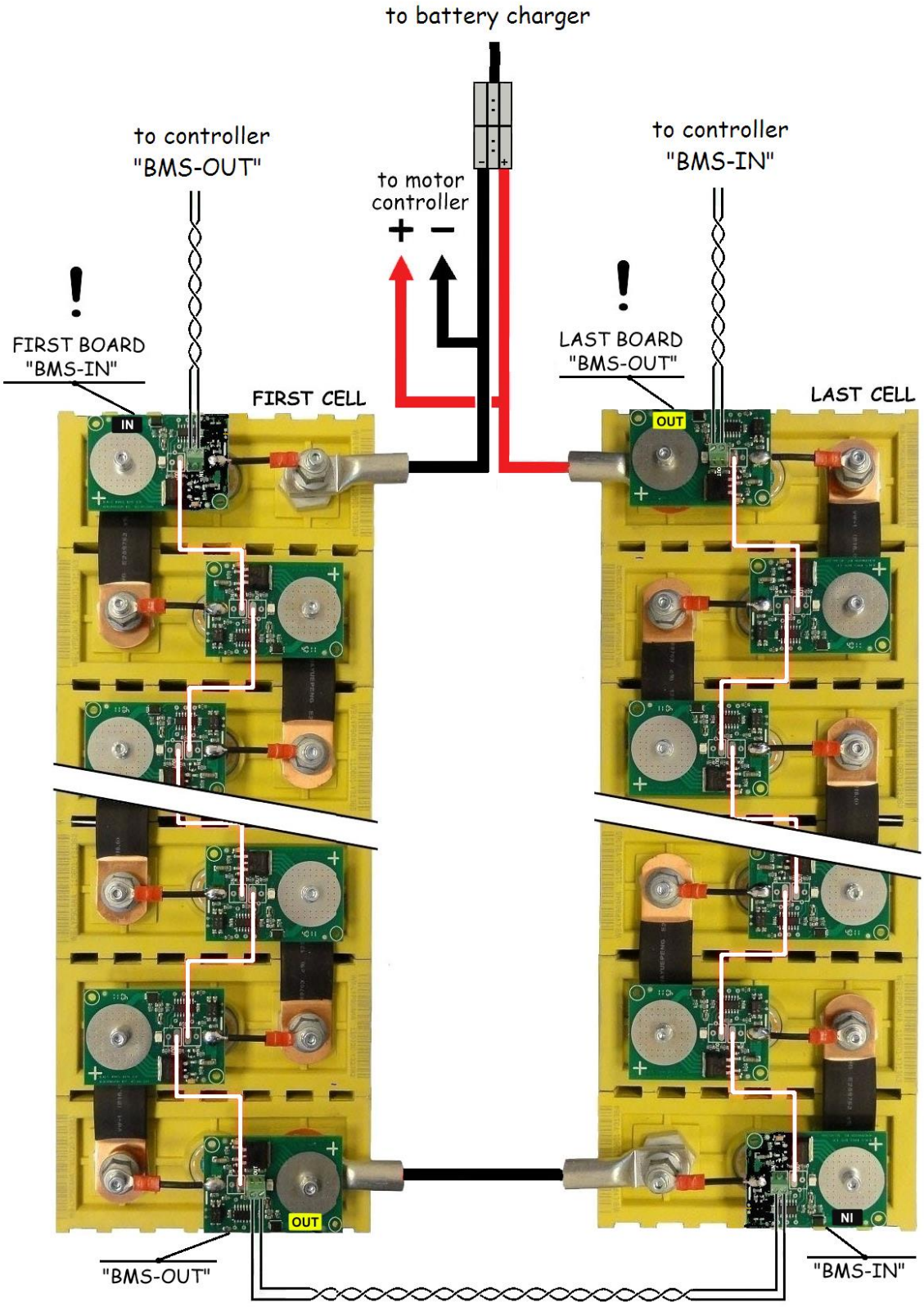
- When the LED is lightning continuous the Cell voltage has reached the By-pass voltage. From now on the cell board will dissipate 1 Amp in to heat. **WARNING:** The black transistor will be hot!

If the communication error sign light op in the electronic dashboard there is something wrong with the communication between the cell boards. The controller tries every 8 seconds to send a new message to the boards. You can easily find the problem by visual inspection. The location where the flashing LED's stop working causes the problem. Please check the interconnection, dust, short circuits etc……

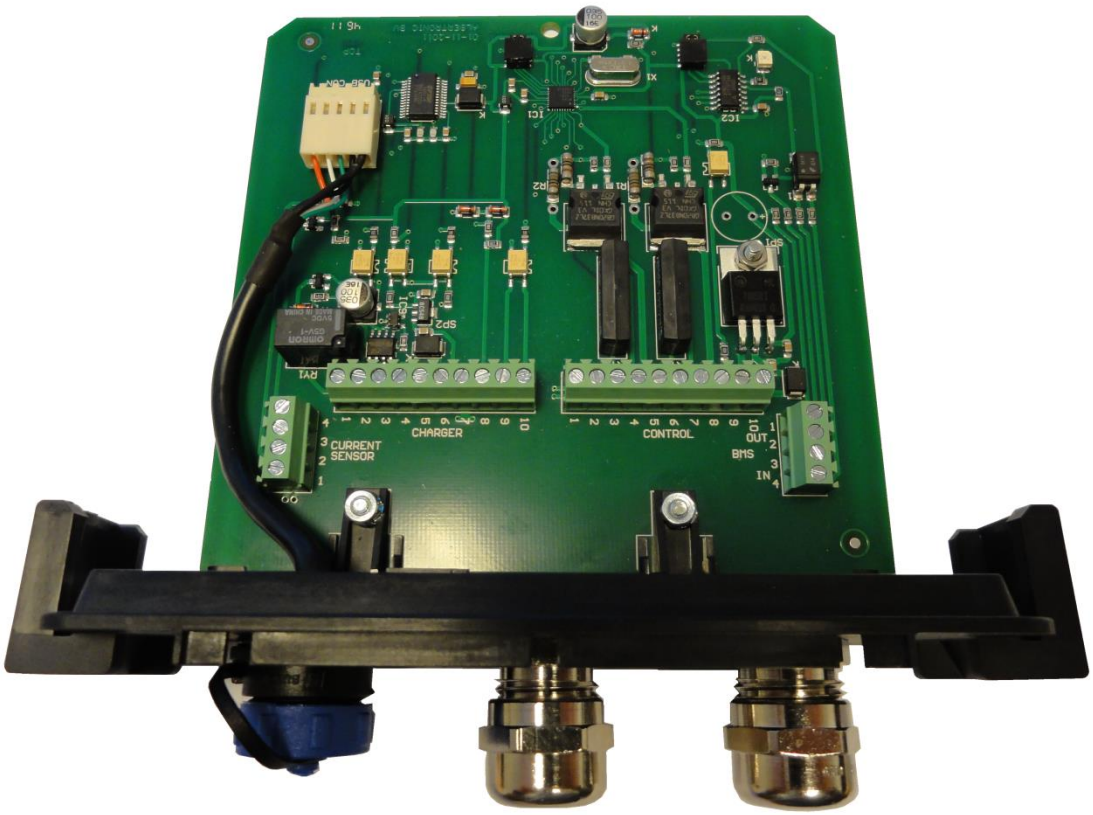
# TC / Elcon wiring diagram overview



# Split pack wiring overview



# Controller connections




**Charger:**

1. Not Connected
2. Not Connected
3. Not Connected
4. Enable (for analog controlled TC/Elcon charger)
5. 12 Volt Input (for analog controlled TC/Elcon charger)
6. Ground (for analog controlled TC/Elcon charger)
7. Not Connected
8. Not Connected
9. Not Connected
10. Not Connected

**BMS:**

1. BMS out
2. BMS out
3. BMS in
4. BMS in

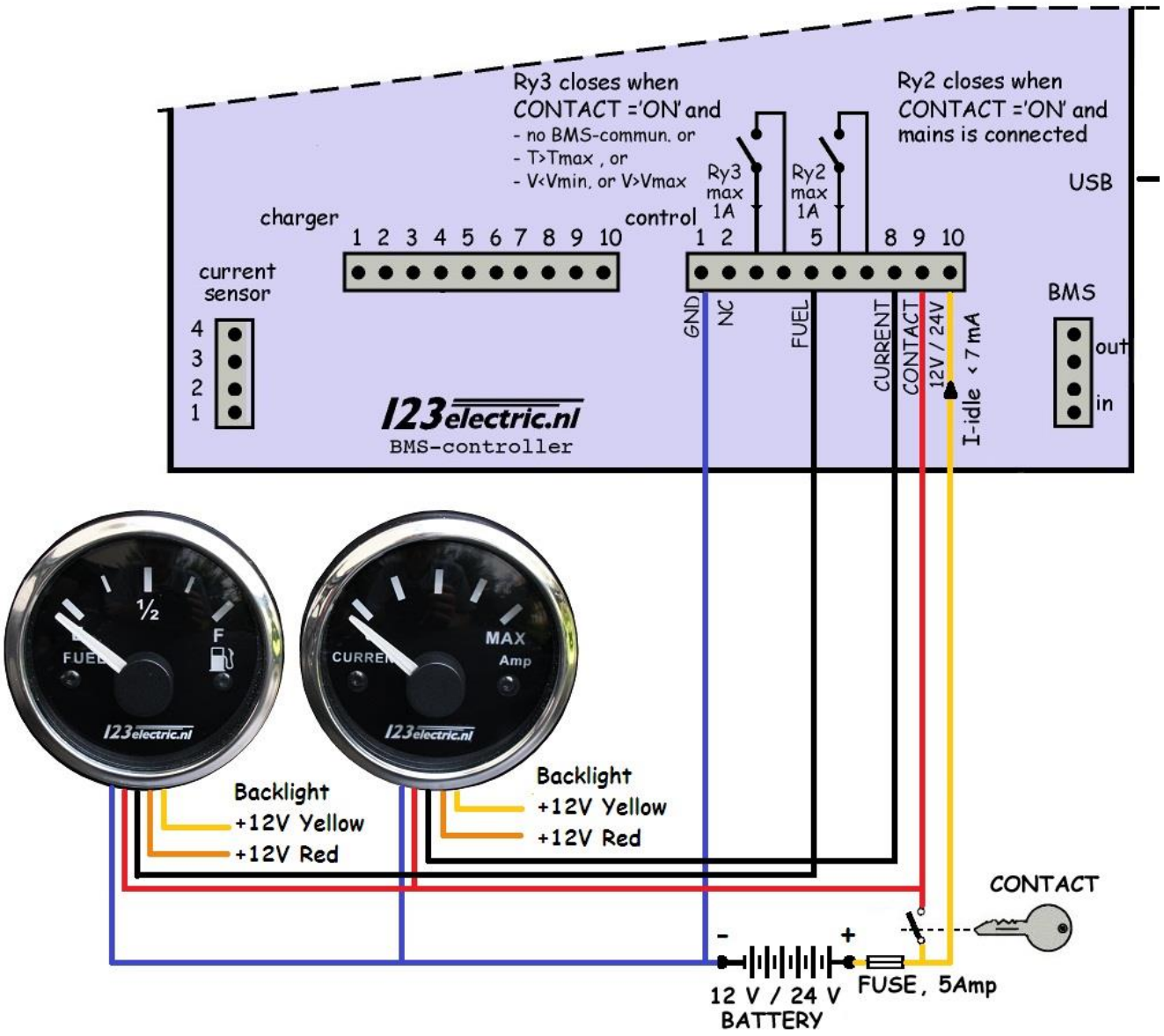
**Current Sensor:**

1. Ground
2. Analog in
3. Switched power to sensor
4. Not Connected

**Control:**

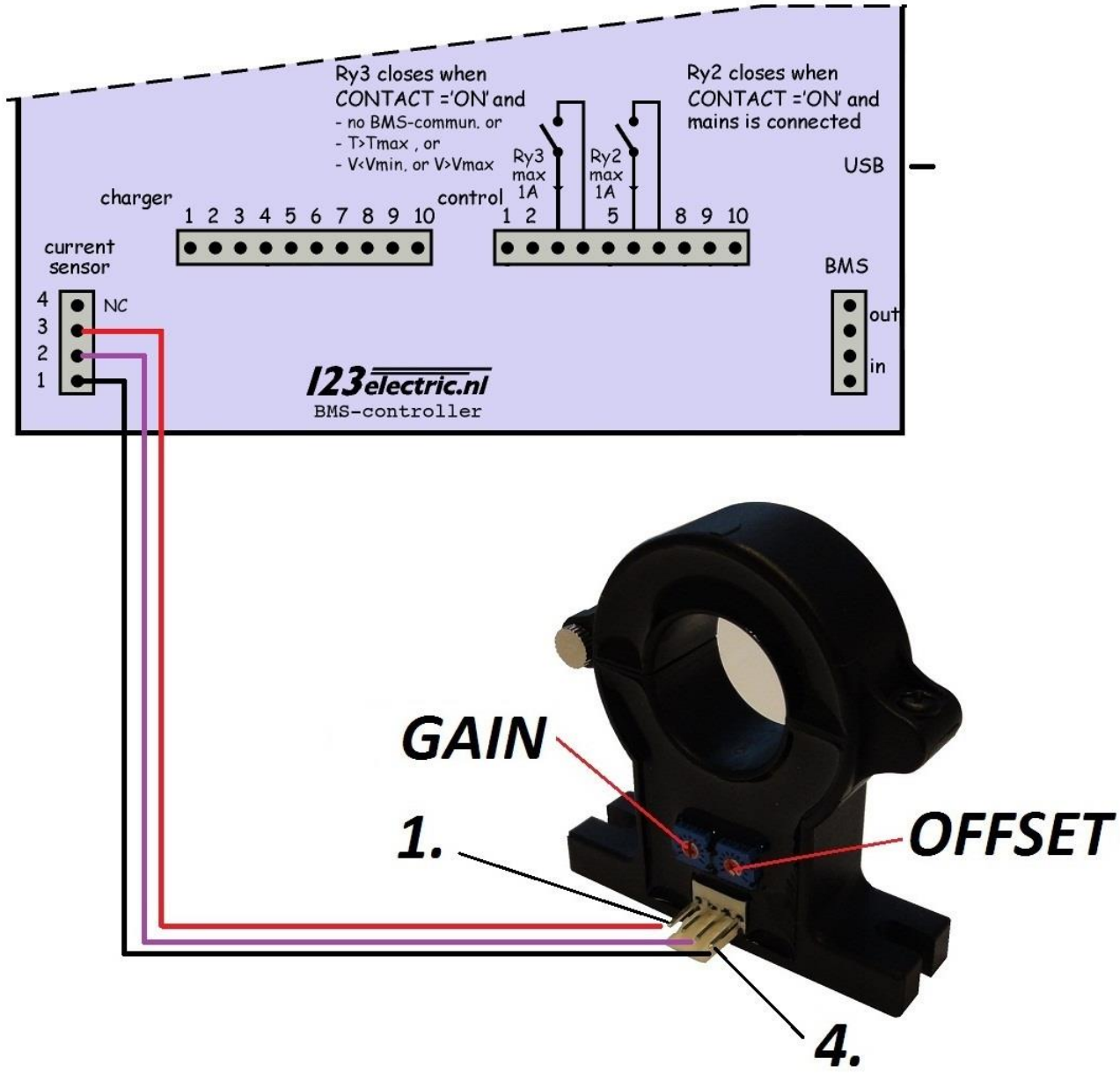
1. Ground
2. Not Connected
3. Relay output 3 ( Closed if BMS-comm. is lost or if T>Tmax or if )
4. Relay output 3 ( V<Vmin or V>Vmax whilst contact is on )
5. Analog 'fuel' gauge output ( Coulomb-counter )
6. Relay output 2 ( Closed if Mains connected whilst contact is on )
7. Relay output 2
8. Analog current gauge output
9. Switched 12/24 Volt power ( contact )
10. Power supply 12/24 Volt ( permanent connection )

# Boardnet connections




In the above schematic the “123electric” current- and fuel- gauges are drawn. Might you want to use your existing fuel gauges instead, you are free to do so. The BMS controller mimics a variable resistor between 0 and 240 Ohms and therefore practically any fuel gauge can be used. With the help of “analog gauge calibration” in the dashboard-software you should be able to linearize the reading of your gauge.

# Current sensor connections




**Control Unit:**

1. Ground
2. Analog input
3. +5 Volt power
4. NC

**Current sensor:**

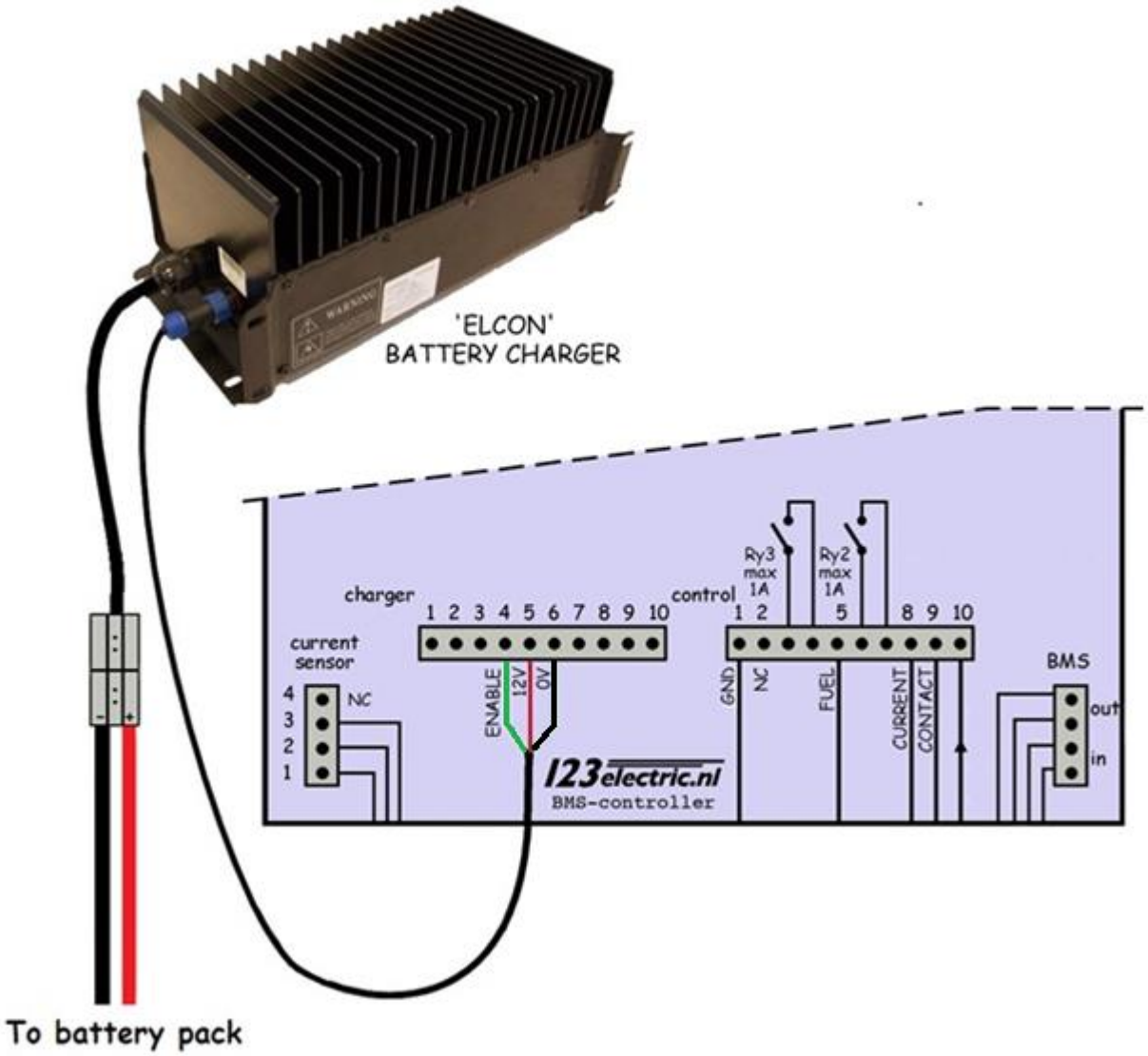
1. +5 Volt power
2. NC
3. Analog output
4. Ground

**Notes:**

- Connect everything correctly, prevent making a wrong connection.

- Two potentiometers can be adjusted by turning slowly to the required accuracy with a small screwdriver.

# TC/Elcon charger connections



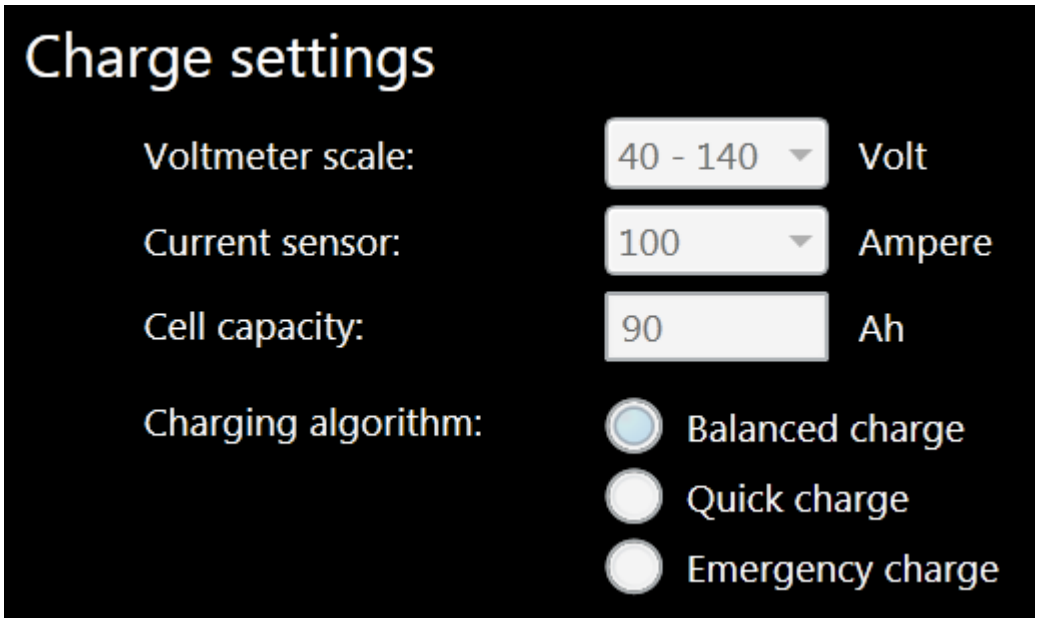

**Control unit:**

| | |
|---|---|
| Enable( Green ) | Pin 4 |
| 12 Volt( Red ) | Pin 5 |
| Ground ( Black ) | Pin 6 |

**TC/Elcon charger:**

Standard TC/Elcon connector-
& cable ( supplied with the charger )

# Software settings




**Voltmeter scale:**

In this part of the settings menu you can select one of five different volt meters on the electronic dashboard for the correct reading of your pack voltage :

10 – 60 Volt
40 – 140 Volt
100 – 200 Volt
150 – 300 Volt
250 – 500 Volt

**Current sensor:**

The 123BMS can work in conjunction with one of three different current sensors. Chose the one that you ordered :

100 Ampere
200 Ampere
400 Ampere

Note: selecting another current sensor will automatically select another current-scale on the electronic dashboard.

Note: changing current-sensor and/or capacity results in the preset to 100% of the Coulomb-counter.

**Cell capacity:**
The cell capacity can of course be set to the capacity of the cells used. We advise however to take only 70% of the rated capacity, to comply with cell aging and temperature effects.

Example: if you have 90 Ah cells, enter 65 Ah in the capacity field.

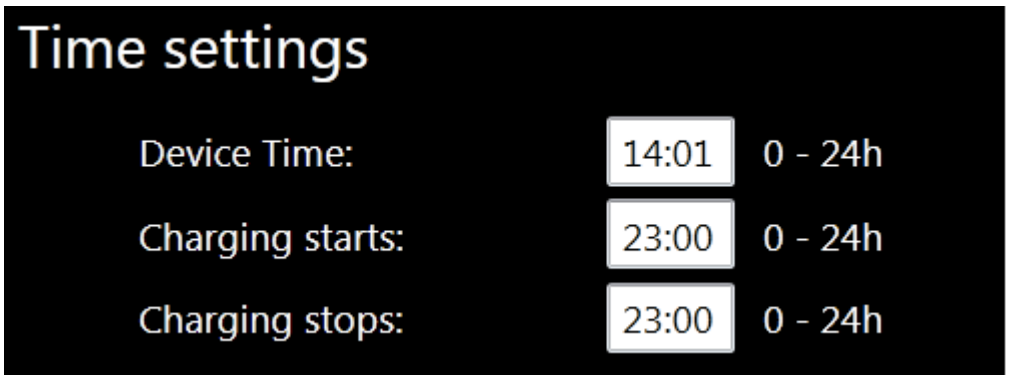
**CHARGING ALGORITHM :**

***Balanced charge:***
When the charging-process begins, the current slowly increases to the maximum charging current selected , until one of the cells reaches the bypass-voltage. At that point the charging-current will ultimately be reduced to the minimum charging current selected.
Charging ends when one of the cells reaches the maximum cell voltage OR when all cells reach the bypass-voltage.

Note: We advise to use balanced charge at least regularly but certainly when the battery pack is new. When you replace one of the cells in a pack ( or for “priming” for instance ) balanced charge may come in handy.

***Quick charge:***
After the charging-process begins, the current slowly increases to the maximum charging current selected, until one of the cells reaches the maximum-voltage OR all cells reach the bypass-voltage. At that point the charging ends.

***Emergency charge:***
In a situation where BMS communication is lost (Cell Voltage much to low or cable rupture) it would become impossible to charge the battery pack. For this situation emergency charge can be selected in the electronic dashboard. Charging will start **even without BMS communication**. Your supervision is vital here as you can imagine. After a period of 30 minutes the charging process will be stopped anyway for this reason.

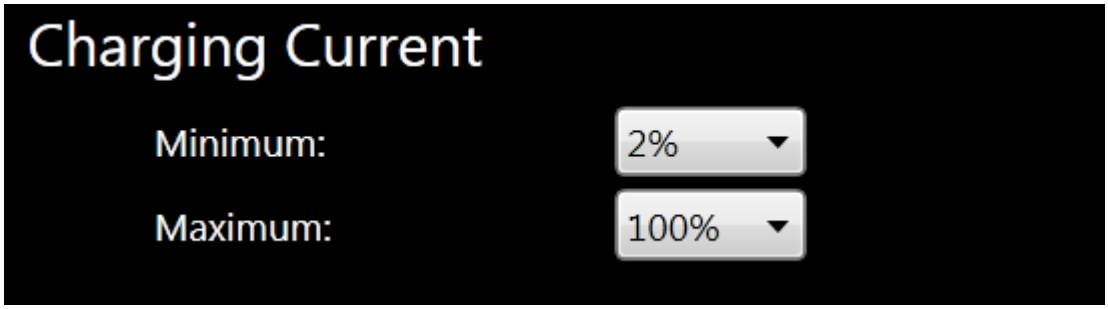



**Device time:**
Here you can enter the time in a 24h fashion. The realtime clock will be kept up-to-date as long as 12 / 24 Volt will be supplied to the unit.

**Charging starts:**
Here you can enter the time after which charging is permitted. Charging only will be enabled at the moment that the device time equals the start time.

**Charging stops:**
Here you can enter the time after which charging is not permitted. Charging only stops at the moment that the device time equals the stop time.

**Important:**
**If the start- and stop- time are equal charging will <u>always</u> be enabled.**




**Minimum:**

The final current after balanced charging should approach the 1 Ampere bypass-current of the BMS boards. The minimum can be set from 2% to 17% of the maximum charging current supplied by your charger.

Example: Maximum charging current is 30 Ampere.
1 Ampere would be 3.3% → Select 4% as minimum charging current.

**Maximum:**

The maximum charging current can be set to 20%, 40%, 60%, 80% and 100%. This feature may come in handy when you are in a situation where only reduced current is available.

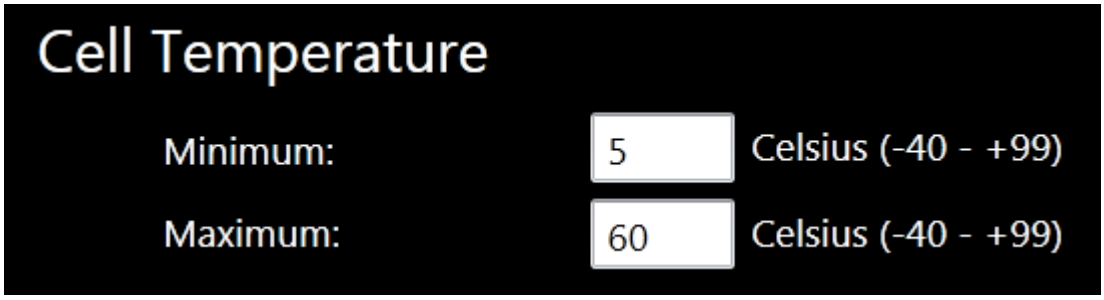
Example: assume that you have only 230 Volt, 6 Ampere available ( 1380 Watt ) and you have a 3000 Watt charger. If you set the maximum current to 40% you will only use 1200 Watt. Take into account that charging time will increase accordingly.

**Minimum:**
If one of the cells gets below this threshold the “L“ -indicator on the electronic dashboard is switched on, and the error relay ( Ry3 ) will be activated provided the contact is on. ( factory-setting is 2.50 Volt )

**Maximum:**
If one of the cells gets above this threshold the “H“ -indicator on the electronic dashboard is switched on, and the error relay ( Ry3 ) will be activated provided the contact is on. ( factory-setting is 3,75 Volt )

**Bypass:**
This is the voltage where you want all the cells to end up. When you have selected balanced charging you will get to this situation every charging cycle. In quick charge mode however it may take several cycles. ( factory-setting is 3,40 Volt )

**Recharge Threshold:**
Assume you leave your electric vehicle connected to the mains for a long time. Obviously you don’t want to start a charging cycle every day but you want to keep your battery pack up to date. So, if one of the cells gets below the recharge threshold a new charging cycle will start. ( factory-setting is 3,00 Volt )

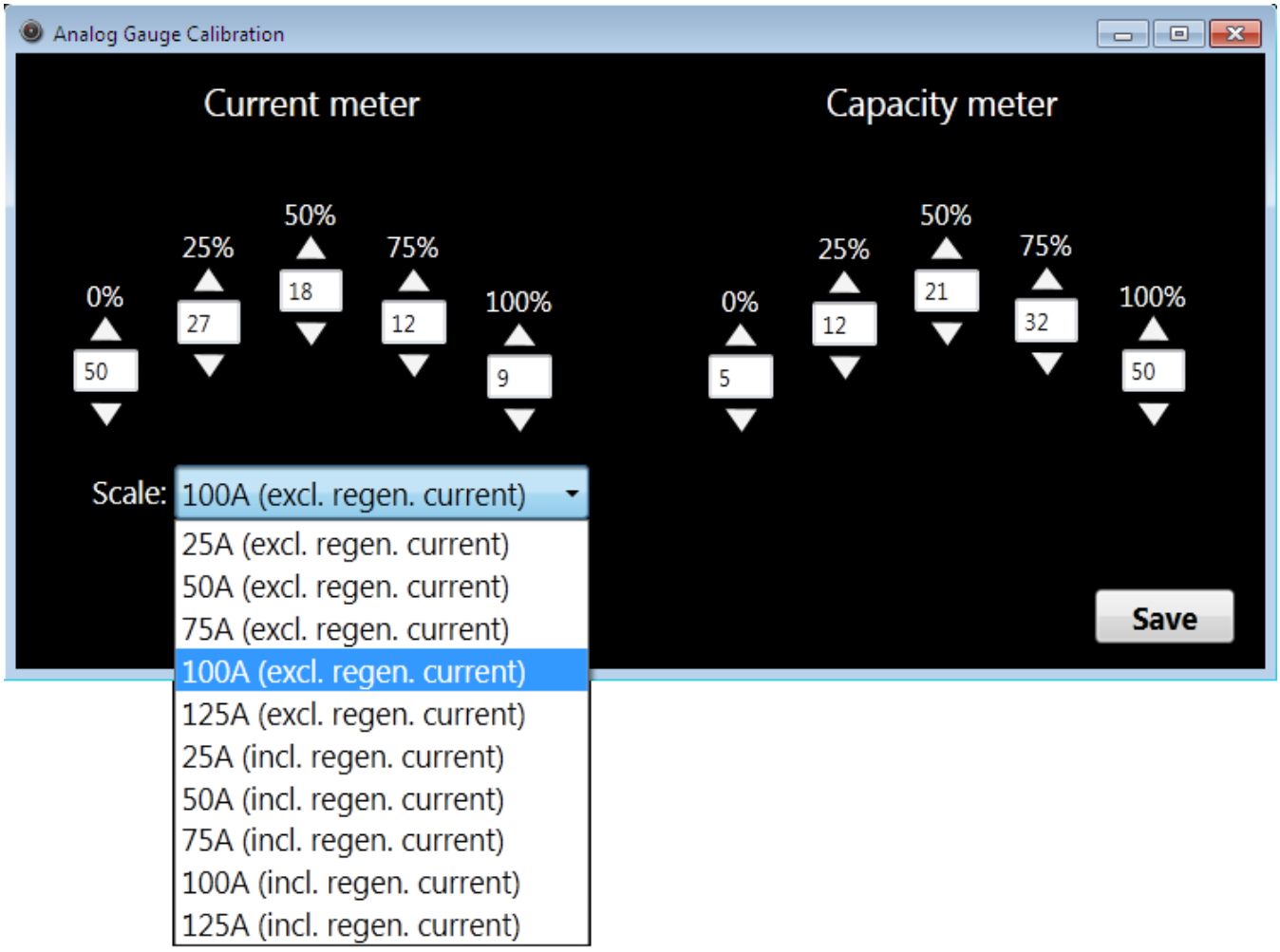



**Minimum:**
If one of the cells gets below this threshold the “L“-indicator on the electronic dashboard is switched on. Both ‘Balanced charge’ and ‘Quick charge’ will be suspended as long as one of the cells are below the minimum temperature set. ( some battery chemistries may not be charged below zero degrees Centigrade )
The charging-process will re-start immediately when the cell-temperature is within the safe area selected. ( factory-setting is 0 degrees Celsius )

**Maximum:**
If one of the cells gets above this threshold the “H“-indicator on the electronic dashboard is switched on, and the error relay ( Ry3 ) will be activated provided the contact is on. ( factory-setting is 60 degrees Celsius )

**Note 1:**
**Ry3 will be activated when the communication with the BMS boards is lost, and/or when the cell-temperature exceeds the maximum, and/or when the cell-voltage exceeds its limits. (provided the contact is on)**

**Note 2:**
**On the electronic dashboard three red lamps are shown “E”, “L” & “H”.**
**The “E” lamp is active when there is no BMS communication.**
**The “L” lamp is active when V<V-MIN and/or T<T-MIN**
**The “H” lamp is active when V>V-MAX and/or T>T-MAX**

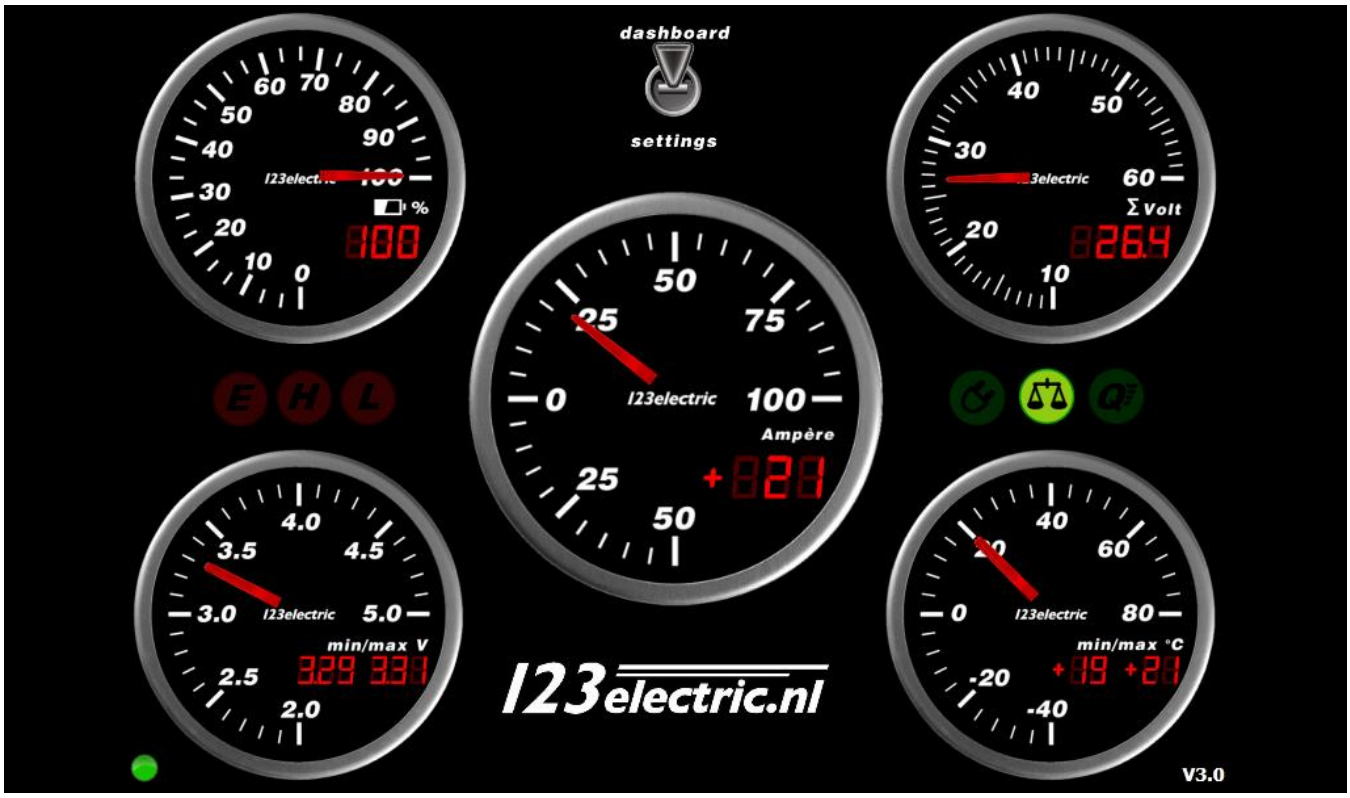
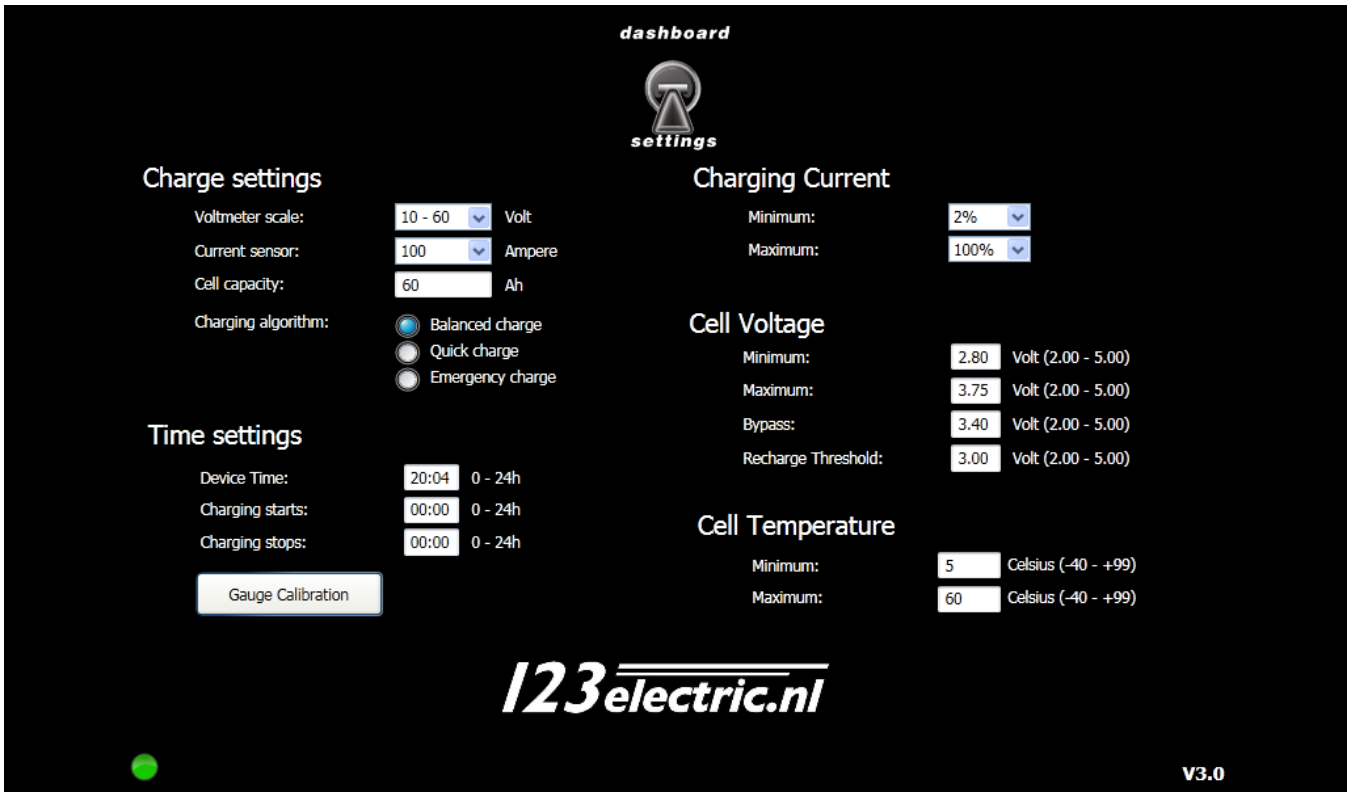



**Analog Gauge Calibration:**

By pressing the Gauge Calibration button in the settings menu you will see the above calibration window. After having selected the proper current sensor in the settings menu you can now select the scale of the current meter on the car dashboard. The pull-down menu will speak for itself, the first five options do not display regenerative current, whilst the last five do. Note that the regenerative current will be displayed as a positive current.

In order to linearize your specific gauge the following procedure is necessary:

1. Remove the wire to pin number 9 ( contact ) of the control connector and prevent short circuit.
2. Switch on the contact key ( the gauges will get 12 Volt supply voltage )
3. From gauge calibration mode select for instance 50% for the current meter. The meter should now read 50%; if it does not read 50% press the “up” or “down” arrow until it does read the required 50%.
4. Repeat step 3 for all the other values and, once you’re happy, press “Save”!

**Notes:**
**-Make sure you do this procedure using the right battery voltage, as analog gauges are quite sensitive for varying supply voltage.**
-**Might you have a 24 Volt battery, and you want to connect the analog 123electric gauges, follow the instructions that come with the gauges.**

# Screen-shots 'electronic dashboard'